THOUSAND WORDS

A thousand words about cardiac mobile health

Vincent Noori, Przemysław Guzik

Department of Cardiology – Intensive Therapy and Internal Medicine, Poznan University of Medical Sciences, Poland

ABSTRACT

Cardiac mHealth (mobile health) is an innovative method of integrating technological and medical advances to provide healthcare in a convenient and cost effective manner in cardiology. While still considered an experimental and upcoming technology, its potential use in cardiology is feasible and may soon replace some standard medical practices. From basic encouragement of lifestyle modification to chronic disease self-management, mHealth can be a personal "pocket-doc". It can provide personal health benefits and immediate life-saving interventions to those who are unable to access medical care. mHealth's potential has much to offer to both physicians and patients.

Keywords: mobile health, cardiology, smart devices, smart applications, telemonitoring.

Mobile devices, which are like small computers, affect every aspect of our lives, including medicine and healthcare, and mobile health (mHealth) becomes a new and independent entity [1–6].

In this mini-review we describe cardiac mHealth. The term mHealth depicts *medical and public health practice supported by mobile devices, such as mobile phones, patient monitoring devices, personal digital assistants, and other wireless devices* [4]. This definition will certainly extend as new solutions and devices are developed, tested and introduced to the health market. Some additional devices not mentioned above include wearable patches that can be attached to a patient's skin for continuous monitoring 24 hours/day (e.g., ZephyrLife, Zephyr™, USA) and implantable devices (e.g., InSYNC pacemakers from Medtronic, cardioverters-defibrillators (ICD) or cardiac resynchronization therapy (CRT) devices), which transfer clinical data to monitoring centers via mobile phones [7–10]. A list of different devices with cardiac mHealth potential is presented in **Table 1** with some examples in **Table 2** [7, 8, 11–15]. A schematic mHealth data flow to and from a patient is pictured in **Figure 1**.

Potential indications for cardiac mHealth

An increasing number of cardiac mHealth solutions are used to solve different problems for a variety of users including patients, their families, healthy people, medi-cal professionals, health care providers, and insurance services [1–6, 16]. The data and information flow in cardiac mHealth is shown in **Figure 2** whereas a list of potential indications and applications of cardiac mHealth is presented in **Table 3**.

Most commonly, cardiac mHealth is applied as a source of information and education. Patients find information on different health-related topics: a diet for weight reduction, smoking cessation, non-pharmacological control of blood pressure or how to safely perform physical exercise [1–4, 6, 16, 17]. Medical professionals search different resources for information on specific drugs or normal laboratory values.

Dozens of smart phone applications (apps), usually free of charge, measure pulse rate directly on mobile devices – an instant measurement of the rate of capillary pulsation is started right after placing a patient's finger on the smartphone's camera. The obtained signal of pulse rate can be further analyzed for computing heart rate variability to describe the autonomic influences on the heart [18].

The use of mHealth as a medical alert the next possible indication, by reminding individuals to take medication or measure glucose level, or by informing the patient about potential progression or aggravation of clinical condition (e.g., extremely high blood pressure or increased lung congestion) [10, 16].

Table 1. A variety of devices and solutions supporting cardiac mHealth. Abbreviations: CRT – cardiac resynchronization, ECG – electrocardiography, ICD – implantable cardioverter-defibrillator

Devices & solutions with cardiac mHealth potential
Medical devices directly transferring measured vital signals or parameters via built-in communication mode: *ECG machine, blood pressure monitor, cardiac impedance monitor*
Medical devices transferring measured vital signals/parameters via other mobile device: *blood pressure monitor*
Medical accessory measuring vital signals/parameters connected to or communicating with a mobile device: *ECG electrodes, heart rate belt*
Medical application installed in a mobile device: *smart applications for instant heart rate*
Medical patch attached to skin measuring vital signals/parameters communicating with a mobile device: *patches measuring ECG, respiration, temperature, activity, position etc.*
Implanted medical device/sensor used for the treatment or diagnosis communicating with a mobile device: *pacemaker, ICD, CRT, implantable loop recorder*

Table 2. List of sample devices and solutions with mHealth potential [11–15]. **Abbreviations: CPR – cardiopulmonary resuscitation, ECG – electrocardiography, EEG – electroencephalography, ICD – implantable cardioverter-defibrillator**

Examples of cardiac mHealth devices & solutions	
Implantable cardioverter defibrillator	A modern ICD is able to remotely communicate with the monitoring center after any intervention or report the current status of the device and electrodes
PocketCPR	This device offers instructions for bystanders to provide effective life-saving chest compressions in case of cardiac arrest
Zypher BioHarness 3 belt	This device performs accurate physiologic monitoring of numerous parameters including heart rate, blood pressure, and respiratory rate among others in a variety of real world conditions
AliveCor Heart Monitor	This smartphone accessory takes electrical impulses from patient's skin to record ECG at any time and anywhere and transmits data to most mobile devices
Flexible Skin-Worn Patch Monitor	These electronic patches can accurately monitor ECG and EEG under a variety of real world conditions
LIFENET 5.0	This mobile application offers physicians the ability to perform rapid consults, provide management decisions, notify appropriate healthcare services of patient condition and arrival, and provide monitoring of patient status all from a mobile device wherever they may be
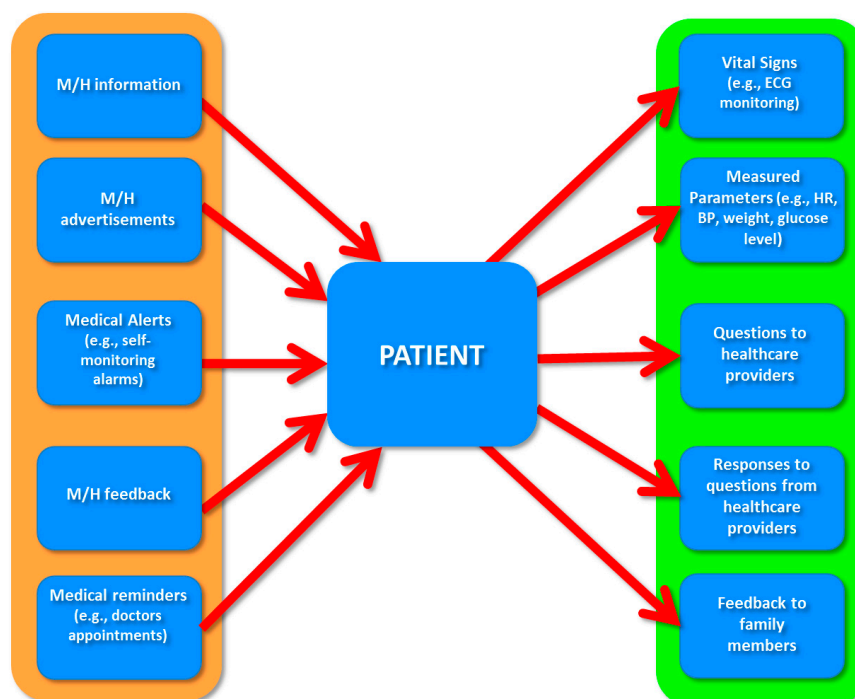
Figure 1. Type of mHealth data generated by or sent to patients. Abbreviations: BP – blood pressure, ECG – electrocardiography, HR – heart rate, M/H: Medical/Healthcare

Another excellent example of mHealth is a system for remote rapid consults in critical conditions (e.g., acute coronary syndromes) and fast clinical decisions (Lifenet 5.0 package, Physiocontrol, USA) [15]. This application can automatically activate special protocols helping hospital teams to prepare in advance for an incoming patient with a heart attack.

The cardiovascular risk assessment is an additional cardiac mHealth application to determine risk profile and the necessity of prescribing a statin. This can be done by using the SCORE (Systematic Coronary Risk Evaluation) Risk Chart available on a mobile app [19] or by the atherosclerotic cardiovascular disease (ASCVD) estimator [20].

The application of mHealth for diagnostic purposes is still in the preliminary phase and its use is mainly restricted to medical doctors. AliveCor is an accessory connected to a mobile phone which takes patient's ECG – it may help to diagnose myocardial infarction or ischemia [13].

The next instance for mHealth is the monitoring of the effectiveness of medical therapy. This can be done in several ways by professional medical devices like blood pressure monitor, glucometer or body composition analyzer, which control specific parameters and send readings to monitoring centers. One very specific mHealth solution that can be applied by anyone, including bystanders, is PocketCPR either installed on a smartphone (ZOLL Medical Corporation, USA) for free or purchased as a separate small device (BIO-DE-TEK Inc, USA) [11]. In both cases, the smartphone or device is held in both hands of a person performing cardiopulmonary resuscitation while it provides a real-time feedback and guidance through the entire resuscitation, improving the effectiveness and success rate.

Some other examples of mHealth are advanced solutions that allow monitoring and transmitting short ECGs with arrhythmias after activation by a patient,
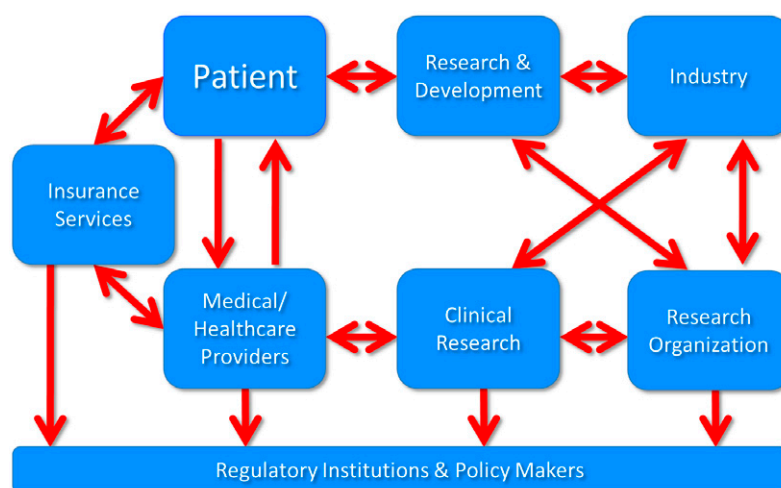

Figure 2. Data and information flow in mHealth

Table 3. Potential indications and applications of cardiac mHealth. Abbreviations: CRT – cardiac resynchronization, ECG – electrocardiography, ICD – implantable cardioverter-defibrillator, ILR – implantable loop recorder, INR- international normalized ratio

Potential indications & applications of cardiac mHealth
FOR PATIENTS
Assessment of the risk of various cardiovascular diseases and their complications
Assessment of the risk of various cardiovascular invasive procedures
Monitoring of vital signals and selected parameters in high-risk patients (*e.g. with recurrent arrhythmia or syncope*)
Education of patients and their family members on cardiovascular risk, prevention, and algorithms of action in case of life emergency
Regular reporting on various cardiovascular measures (*e.g. blood pressure, heart rate, INR*)
Remote monitoring of implanted devices, long-term skin patches with measuring vital signals
FOR MEDICAL PROFESSIONALS
Remote control of the effectiveness of therapy and progress of cardiovascular disease (*e.g. heart failure*)
Remote assistance in cardiac rehabilitation (*post-infarction, heart failure, post cardiac surgery*)
Remote control of implanted therapeutic (*pacemaker, ICD, CRT*) and diagnostic (*ILR*) devices
Remote reading and monitoring of selected vital signals and parameters in high-risk patients
The need of regular and repeated education of patients and their family members

family member or witness. The ECG tracings can also be automatically sent via an implanted device (e.g., ICD) directly to monitoring centers [7–9, 12, 15].

Potential benefits of using mHealth

It is rather a matter of a short time when cardiac mHealth will be routinely used and prescribed – a small medical application can easily turn a standard smartphone into a professional medical device.

There are many potential benefits for the application of cardiac mHealth (**Table 4**) like acquiring real-time monitoring of vital signals, collecting clinical data on a large scale, reduction in costs of healthcare, which is particularly important in low-income and developing countries, and improved personalization of the medical treatment [1, 3, 4–8, 10, 16, 17, 18, 21, 22, 23].

Potential mHealth related risks and limitations

The capability of cardiac mHealth is anticipated to be one of the fastest growing areas in medicine and has also prompted research for its use in other areas (engineering, programming etc.) [1–4, 6, 7, 8, 23, 24]. However, the application of mHealth can be accompanied by risk (**Table 5**) some of which may convey an increased cardiovascular morbidity and mortality [2, 3, 4, 21]. The responsibility of using and prescrib-

Table 4. Potential benefits of cardiac mHealth for the general population, patients, medical practitioners, and healthcare providers

Benefits of using cardiac mHealth
Collecting community and clinical data at low cost and real time
Continuous delivery of updated healthcare information and services to practitioners, researchers, and patients at any time
Real-time monitoring of patient's vital signs
Provision of healthcare in a convenient and cost effective manner
Portability of mHealth devices – a "pocket-doc"
Encouragement of health and self-surveillance for patients
Supporting mHealth contemporary solutions in developing nations
Beneficial interventions and programs on health in both high- and low-income countries
Accessibility from home and any place to mHealth with a reduction in number of office visits patients need to make
Easier and faster communication with medical personnel
Automatic data collection that are sent directly to medical personnel, monitoring centers, researchers and developers, clinical scientists, and insurance system
Increasing patient's mobility and ability to travel even for those who have chronic cardiovascular diseases
Easier communication with patients and their families
Ability to review patient data and determine course of management from anywhere
Ability to communicate course of management to patient and their families
Reduction of costs of diagnosis, monitoring, prophylaxis, risk assessment and treatment in selected diseases.
Transfer of some medical procedures closer to patient's natural environment
More personalized approach to health and medical care

Table 5. Potential risks of cardiac mHealth for general population, patients, medical practitioners and healthcare providers

Risks of using cardiac mHealth
Not established standards for medical and sensitive data transfer between different users of mHealth
Dependence on the availability of access to communication network
Not standardized protocols, algorithms, sensors with a variety of mobile devices which are not primarily medical devices
Lack of personal responsibility for taking decisions
Lack of legal regulations for using mHealth
Lack of reimbursement from insurance systems
Troubles with using advanced mHealth solutions by substanial number of people not familiar with modern internet & communication technologies
Lack of data from prospective, multicenter and randomized trials
Lack of recommendations of using mHealth in specific cardiovascular problems or prophylaxis
Lack of controlling institutions ready to certify mHealth solutions
Massive development of unverified medical and health-related smart apps by people with no medical background, expertise and skills
No certificates for majority of mHealth solutions
No assistance in choosing right mHealth solution for specific cardiovascular problems
Lack of face-to-face contact between patients and medical/health care professionals
Misunderstanding of instructions, comments, questions and answers from medical/health care professionals

ing mHealth is undetermined and it is unclear whether insurance companies will reimburse mHealth. As of right now, there are no legal regulations on mHealth, and the first documents are either in very preliminary forms or are under construction [2, 3, 4, 22].

Nevertheless, the development of cardiac mHealth seems unstoppable – the first mHealth devices and applications have gotten approval from the Food and Drug Administration in USA for the use by medical professionals while many others are being introduced to the market by medical industry without approval from any regulatory institution [2–5].

While mHealth provides a sort of "pocket-doc", there is no replacement for the physical and emotional support or a live personal physician. As with any innovative technological advancement, mHealth comes with its limitations. It may offer advantages in specific aspects of healthcare but its vast reach is not finite. There are neither big, prospective, multicenter and randomized clinical studies exploring the application of mHealth to cardiac patients nor guidelines on the use of cardiac mHealth from any of the largest cardiac societies [3, 4, 5, 17].

Summary

Users adopt the cardiac mHealth tools nearly as quickly as they are developed for different purposes. With the rising popularity of mobile devices, cardiac mHealth has the potential to help modifying lifestyle, aid in chronic cardiovascular disease (e.g., heart failure, hypertension, arrhythmias), self-management and surveillance [1, 3–8, 10, 16, 17, 18, 22, 23, 25, 26]. Cardiac mHealth may improve physician, researcher, and patient understanding of cardiovascular diseases and risk factors, reduce needs for healthcare visits, help to collect community and clinical health data and vital signals, and provide immediate, personalized medical interventions. Cardiac mHealth can bring ease for people to take care of their own health and promote lifestyle changes, and supply immediate access to medical information whenever and wherever they require it.

Acknowledgments

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Correspondence address:
Przemysław Guzik
Department of Cardiology – Intensive Therapy
and Internal Medicine
Poznan University of Medical Sciences
49 Przybyszewskiego Street, 60-355 Poznań, Poland
phone: +48 61 869 13 91
fax: +48 61 869 16 89
email: pguzik@ptkardio.pl